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METHOD AND DEVICE FOR THE CONTROL OF A SAFETY DEVICE IN A VEHICLE

BACKGROUND OF THE INVENTION

[0001] The invention relates to a method for the determination of at least one activation magnitude for a safety device in a vehicle, which can be operated in at least two operational states, where the operational state of the safety device can be changed as a function of a result of a comparison of the activation magnitude with a predetermined threshold value, where, by means of an environment sensor, object data of at least one object in the surroundings of the vehicle are acquired, and where the object data comprise a position of the object, a speed of the object, and a direction of movement of the object. Furthermore, the invention relates to a method for controlling a safety device in the vehicle, which can be operated in at least two operational states, in which method, by means of an environment sensor, object data of at least one object in the surroundings of the vehicle are determined, where the object data comprise a position of the object, a speed of the object, and a direction of movement of the object.

[0002] The invention relates additionally to arrangements for carrying out the method.

[0003] The concept of passive safety is understood, in the automobile technology, to refer to the protection of vehicle passengers from severe consequences of accidents. To ensure this protection, reversible passenger protections are used primarily, whose operating states as a rule comprise one or more active states as well as an inactive state, and which can be changed reversibly by an automatic control mechanism. Examples of such reversible passenger protections are reversible motor-driven belt tighteners (RMBT) which tighten the safety belts and retain the vehicle passengers in their seats in dangerous situations, automatic seat adjustments by means of which the seats can be

brought in an upright position in dangerous situations, as well as electrical window raising devices and electrical setting devices for a sliding roof, by means of which the windows of the vehicle and a sliding roof, if present, can be closed in dangerous situations.

[0004] In contrast to irreversible passenger protections, such as, for example, air bags, which after they have been triggered can only be set to the inactive state by an appropriate automatic control mechanism, the activation of reversible safety devices can already have occurred during the time preceding a potential accident. However, this requires the recognition of an existing traffic situation and its evaluation in view of the possibility of an imminent accident, and of the type and severity of the accident.

[0005] For this purpose, a passenger retention system is known from the German Patent DE 196 36 448 C2, in which a belt tension control mechanism is controlled by a processing unit, which evaluates the signals of an object detector which detects objects in the vicinity of the vehicle. Different operational modes of the belt tension control mechanisms are activated in the process, if the distance between a vehicle and an object located in front of the vehicle falls below safety separations, which are determined as a function of the vehicle speed or the relative speed of the vehicle and the object, or if the time until a collision between the vehicle and an object located on the side of the vehicle occurs, and which is determined as a function of the separation and the relative speed, falls below predetermined threshold values.

[0006] In the known system, the situation-dependent options available to the driver to prevent a collision and their evaluation in particular are still largely not taken into account. In particular, the performed evaluation of the traffic situation can differ considerably from the estimation made by the driver. The control in many situations cannot be executed by the driver, resulting in a reduction of the driving comfort and potentially in safety-endangering irritation for the driver.

[0007] The invention is therefore based on the problem of better adapting the control of a safety device in a vehicle to the existing traffic situation.

SUMMARY OF THE INVENTION

[0008] According to the invention, this problem is solved by a method for the determination of at least one activation magnitude for a safety device in a vehicle, which can be operated in at least two operational states, where the operational state of the safety device can be changed as a function of a result of a comparison of the activation magnitude with a predetermined threshold value, where, by means of an environment sensor, object data of at least one object in the surroundings of the vehicle are acquired, and where the object data comprise a position of the object, a speed of the object, and a direction of movement of the object. In the method, from the object data ($\mathbf{r}^S_{Obj}$, $\mathbf{v}^S_{Obj}$), a first trajectory ($\mathbf{r}^S_{Obj}(t)$) of the object is determined, which is used for the determination of a first length of time (Δt_{pcu}) up to a latest time at which a driving maneuver for preventing a collision with the object must be started, and in that the activation magnitude (dp) is determined as a function of the first length of time Δt_{pcu}. The problem is also solved by a method for controlling a safety device in the vehicle, which can be operated in at least two operational states, in which method, by means of an environment sensor, object data of at least one object in the surroundings of the vehicle are determined, where the object data comprise a position of the object, a speed of the object, and a direction of movement of the object. In the method, from the object data ($\mathbf{r}^S_{Obj}$, $\mathbf{v}^S_{Obj}$), a trajectory ($\mathbf{r}^S_{Obj}(t)$) of the object is determined, which is used for the determination of a first magnitude (dp, t_{tc}), where an operational state of the safety device is changed as a function of a result of a comparison of the first magnitude (dp, t_{tc}) with a predetermined threshold value (S^i_{dp}, S^i_t), and in that the trajectory ($\mathbf{r}^S_{Obj}(t)$) is used for the determination of a second magnitude (σ, θ), where the threshold value (S^i_{dp}, S^i_t) is determined as a function of the second magnitude row (σ, θ).

According to the invention, this problem is solved, furthermore, by an arrangement for the determination of at least one activation magnitude for a safety device in a vehicle, which can be operated in at least two operational states, by means of an environment sensor,

which acquires object data of at least one object in the surroundings of the vehicle, where the object data comprise a position of the object, a speed of the object, and a direction of movement of the object. The risk calculator determines a first trajectory ($\mathbf{r}^S_{Obj}(t)$) of the object from the object data ($\mathbf{r}^S_{Obj}$, $\mathbf{v}^S_{Obj}$), which trajectory is used for the determination of a first length of time (Δt_{pcu}) up to a latest time at which a driving maneuver for preventing a collision with the object must be started, and in that the risk calculator determines the activation magnitude (dp) of the first length of time (Δt_{pcu}). The problem is also solved by an arrangement for controlling a safety device in a vehicle, which device can be operated in two [sic] at least two operational states, with an environment sensor, which acquires the object data of at least one object in the surroundings of the vehicle, where the object data comprise a position of the object, a speed of the object, and a direction of movement of the object. The arrangement includes a risk calculator which is connected with the safety device and which determines a trajectory ($\mathbf{r}^S_{Obj}(t)$) of the object from the object data ($\mathbf{r}^S_{Obj}, \mathbf{v}^S_{Obj}$), which is used for the determination of a first magnitude (dp, t_{tc}) and a second magnitude (σ, θ), the risk calculator determines a threshold value (S^i_{dp}, S^i_t) from the second magnitude (σ, θ), the risk calculator presents a comparison means for carrying out a comparison of the first magnitude (dp, t_{tc}) with the threshold value (S^i_{dp}, S^i_t), and the risk calculator converts a result of the comparison into a control signal for changing the operational state of the safety device.

[0009] The procedure according to the invention for controlling a safety device, which can be operated in at least two operational states, in a vehicle, where said device uses an environment sensor to acquire object data for at least one object in the surroundings of the vehicle, and where the object data comprise a position of the object, a speed of the object, and a direction of movement of the object, is characterized in that, from the object data, a first trajectory of the object is determined, which is used for the determination of a first length of time up to a latest time at which a driving maneuver has to be started to prevent a collision with the object, in that from the first length of time an activation magnitude is determined, and in that the operational state of the safety device is changed

as a function of the result of a comparison of the activation magnitude with a predetermined threshold.

[0010] The term "safety device" here refers to all the measures which, on the one hand, assist the driver in the evaluation of the dangerous situation and the prevention of the potential accident and/or which, on the other hand, contribute to reducing the consequences of a potential accident for the passengers of the vehicle. For the evaluation and the prevention, it is possible, in particular, to provide a warning indicating a potential dangerous situation, and also an automatic or assistive braking of the vehicle. In particular, a reversible safety device denotes the above-mentioned passenger protections, that is, the safety device can be particularly a reversible motor-driven belt tightener, an electrical window raising device, an electrical setting device for a sliding roof, or an electrical seat adjustment. Moreover, such safety devices can be active head supports or electrical knee pads.

[0011] The latest time at which a driving maneuver for collision prevention must be started corresponds to the time after which a collision between the vehicle and the object can no longer be prevented, if the vehicle at that time is on a collision course with the object. The advantage of the invention is thus that the activation magnitude is determined from the length of time that remains until this time is reached, so that the control can occur on a proactive basis and be adapted particularly well to the traffic situation. The evaluation of the traffic situation is thus based on the evaluation made by the driver of the vehicle.

[0012] Consequently, on the one hand, the safety of the vehicle passengers can be reliably increased and, on the other hand, the control of the safety device can be carried out in a manner which can be executed easily on the basis of the activation magnitude for the passengers of the vehicle. Any risk to the passengers and particularly to the driver due to an unexpected triggering of the safety device can thus be prevented, while at the same time the best possible protection for the passengers is ensured.

[0013] Driving maneuvers for preventing a collision with the object include particularly braking the vehicle and engaging in an avoidance maneuver, which is started with a steering movement.

[0014] A particularly preferred embodiment of the invention determines a second length of time up to the latest time at which a braking of the vehicle must be started to prevent a collision with the object, a third length of time up to a latest time at which the steering movement must be started, to prevent a collision with the object, as well as the first length of time which is the maximum of the second length of time and of the third length of time.

[0015] An additional preferred embodiment of the invention determines an additional object, an intersection of a second trajectory and a front vehicle limitation line, as well as a first length of time up to a time at which the object reaches the front vehicle delimitation line, and it does not take into account the third length of time in the formation of the maximum value, if the separation between the intersection of the second trajectory and the front vehicle delimitation line and a vehicle longitudinal axis is less than a predetermined safety separation, and if the fourth length of time is less than a predetermined threshold.

[0016] As a result, it is possible to evaluate avoidance maneuvers in terms of whether sufficient space for avoidance is available. Avoidance maneuvers for preventing a collision between the vehicle and the object, which could lead to a collision of the vehicle with an additional object, are recognized and not taken into consideration in the determination of the third length of time, resulting in a further improvement of the adaptation of the steering to the traffic situation.

[0017] It is preferred for the evaluation of the possible avoidance maneuvers to be carried out separately for avoidance maneuvers in both directions that are transverse with respect to the vehicle, namely to the right and to the left.

[0018] A preferred embodiment of the invention therefore determines the third length of time as the maximum of a length of time $\Delta t_{pcu,st,l}$ up to a latest time at which an avoidance steering movement in a first direction transverse with respect to the vehicle must be started to prevent a collision with the object, and a second length of time $\Delta t_{pcu,st,r}$ up to a latest time at which an avoidance steering movement in a second direction transverse to the vehicle must be started to prevent a collision with the object.

[0019] Furthermore, an advantageous embodiment of the invention determines the length of time $\Delta t_{pcu,st,l}$ for which the maximum value formation for the determination of the third length of time is not taken into account, if the intersection of the second trajectory and the front vehicle delimitation line is within a collision prevention area, and the fourth length of time is less than the predetermined threshold, where the collision avoidance zone is defined by a separation between a point of the front vehicle delimitation line, which is located in the first direction transverse to the vehicle, from the vehicle longitudinal axis.

[0020] Furthermore, an advantageous embodiment of the invention does not take into account the length of time $\Delta t_{pcu,st,r}$ for which the maximum value formation, for the determination of the third length of time, if the intersection of the first trajectory with the front vehicle delimitation line is within a collision avoidance zone, and the second length of time, is less than the predetermined threshold, where the collision avoidance zone is defined by a separation between a point of the front vehicle delimitation line, which is located in the second direction transverse to the vehicle, from the vehicle longitudinal axis.

[0021] Because environment sensors, as a rule, do not allow a determination, or allow only a very imprecise determination, of the dimensions of objects located in the surroundings of the vehicle, an additional preferred embodiment of the invention assigns a collision course safety to a separation between an intersection of the first trajectory with the front vehicle delimitation line and the vehicle longitudinal axis, where the collision course safety corresponds to a probability that the first object and the vehicle are on a

collision course. In addition to this embodiment, other possibilities are provided to determine a collision course safety, which takes into account the possible behavior of the object and/or is based on mathematical models for evaluating the overall traffic situation.

[0022] Furthermore, an advantageous embodiment of the invention determines a safety nonavoidance probability from a relation between the first length of time up to the latest time at which a driving maneuver must be started to prevent a collision with the object, and a predetermined additional length of time. This advantageously corresponds to an estimate of the probability that the driver will not initiate measures to prevent a collision or an accident.

[0023] Moreover, it is preferred to determine a danger potential for an object as a function of the accident nonavoidance probability and the collision course safety. The danger potential here is an estimated probability of collision with the object.

[0024] In a preferred embodiment of the invention, the danger potential is used as an activation magnitude.

[0025] Furthermore, a collision time is advantageously calculated, at which the trajectory of the object intersects the front vehicle delimitation line.

[0026] Another preferred embodiment of the invention uses the collision time as an additional activation magnitude, where the operational state of the safety device is determined as a function of a result of a comparison of the collision time with a predetermined threshold.

[0027] As a rule, several objects are located in the surroundings of the vehicle, for which there are different danger potentials and different collision times.

[0028] A preferred embodiment of the invention determines the trajectories for several objects acquired by the environment sensor, which trajectories are used for the determination of the first length of time for each one of the objects with a non vanishingly low collision course safety, a minimum value of the determined first generated length of times Δt_{pcu}, and the activation magnitude dp, t_{tc} from the generated minimum value.

[0029] It is advantageous to determine the trajectories for several objects acquired by the environment sensor, which trajectories are used for the determination of the first length of time for each object with a non vanishingly low collision course safety, a minimum value of the determined collision time t_{tc}, and the activation magnitude dp from the object data of the object chosen on the basis of the minimum value.

[0030] In this manner, the activation magnitude is determined using the first length of time up to the latest time at which a driving maneuver must be started to prevent a collision with the object which is responsible for the highest risk to the vehicle or the passengers.

[0031] An additional embodiment of the invention provides the same advantages, namely by determining a danger potential for each one of the several objects acquired by the environment sensor and the maximum value of the determined danger potentials, and by using the maximum value as an activation magnitude.

[0032] Another advantageous embodiment of the invention determines a collision time for several objects acquired by the environment sensor and uses the earliest determined collision time as an additional activation magnitude.

[0033] In addition, a method is described for controlling a safety device in a vehicle, which device can be operated in at least two operational states, where at least object data of at least one object in the surroundings of the vehicle are determined by an environment sensor, and the object data comprise a position of the object, a speed of the object, and a direction of movement of the object, which method is characterized in that, from the

object data, a trajectory of the object is determined, which is used for the determination of a first magnitude, where the operational state of the safety device is changed as a function of a result of a comparison of the first magnitude with a predetermined threshold value, and in that the first trajectory is used for the determination of a second magnitude, where the threshold is determined as a function of the second magnitude.

[0034] As a result, the threshold value, with which the first magnitude is compared for the activation of the safety device, can be adapted, using the second magnitude, to the existing traffic situation. In particular, during the activation, the type of potential accident can be taken into account and can be characterized by means of the second magnitude.

[0035] In an advantageous embodiment of the invention, the second magnitude concerns the accident severity, where the accident severity is assigned to the relative impact speed of the object and of the vehicle.

[0036] In an additional embodiment of the invention, the second magnitude is a collision angle between the vehicle and the object.

[0037] The first magnitude is advantageously a collision time, at which the trajectory of the object intersects the front vehicle delimitation line.

[0038] In a preferred embodiment of the invention, the first magnitude is an activation magnitude, which is determined in a prescribed manner.

[0039] In an advantageous embodiment of the invention, the safety device is a reversible safety device.

[0040] In an additional advantageous embodiment of the invention, the safety device is a reversible motor-driven belt tightener.

[0041] Furthermore, the invention makes available a arrangement for the control of at least one activation magnitude for a safety device in a vehicle, which device can be operated in at least two operating states, with an environment sensor which acquires the object data of at least one object in the surroundings of the vehicle, where the object data comprise a position of the object, a speed of the object, and a direction of movement of the object, which arrangement is characterized in that the risk calculator determines a first trajectory of the object from the object data, which trajectory is used for the determination of a first length of time up to a latest time at which a driving maneuver for preventing a collision with the object must be started, and in that the risk calculator determines the activation magnitude from the first length of time.

[0042] In a preferred embodiment of the invention, the risk calculator presents a comparison means for carrying out a comparison of the activation magnitude with a threshold value and the risk calculator converts a result of the comparison into a control signal to change the operational state of the safety device.

[0043] In addition, the invention makes available an arrangement for controlling a safety device in a vehicle, which device can be operated at least in two operational states, with an environment sensor which acquires the object data of at least one object in the surroundings of the vehicle, where the object data comprise a position of the object, a speed of the object, and a direction of movement of the object, which arrangement is characterized in that it comprises a risk calculator connected with the safety device, which determines a trajectory of the object from the object data, which trajectory is used for the determination of a first and a first a second [sic] magnitude, in that the risk calculator determines a threshold value from the second magnitude, in that the risk calculator comprises a comparison means for carrying out a comparison of the first magnitude with the threshold value, and in that the risk calculator converts a result of the comparison into a control signal for changing the operational state of the safety device.

[0044] Additional advantages, special features and advantageous variants of the invention are indicated in the following representation of preferred embodiment examples with reference to the figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0045] In the figures:

[0046] Figure 1 shows an illustration of a fixed reference system, called the sensor system, and particularly an illustration of the coordinate axes of the reference system,

[0047] Figure 2 shows a diagram to illustrate a classification of objects,

[0048] Figure 3 shows an illustration of the trajectory of an object and its cross section with a front vehicle delimitation line,

[0049] Figure 4a shows an illustration of a reflection point of the sensor signal for an object located in the driving lane of the vehicle,

[0050] Figure 4b shows an illustration of a reflection point of the sensor signal for an object which is offset with respect to the driving lane of the vehicle,

[0051] Figure 4c shows an additional illustration of a reflection point of the sensor signal for an object which is offset with respect to the driving lane of the vehicle,

[0052] Figure 5 shows a diagram with a potential curve group for the determination of the collision course safety,

[0053] Figure 6 shows a diagram for the determination of an object's dimensions,

[0054] Figure 7 shows a characteristic line for the determination of the accident severity, and

[0055] Figure 8 shows a flow diagram to illustrate the control of a RMBT.

DETAILED DESCRIPTION OF THE DRAWINGS

[0056] For the control of the safety device, a risk calculator, which uses data on objects located in the surroundings of the vehicle, which are measured by means of an environment sensor, determines the instantaneous traffic situation and calculates future traffic situations. The future traffic situations are evaluated by the danger calculated in view of a potential collision between the vehicle and an object acquired by the environment sensor, in order to carry out a situation-adapted control of the safety device.

[0057] The risk calculator is preferably a processing unit which works in cycles for processing the measurement signals of the environment sensor, and which has particularly a means for carrying out computations and a volatile and/or nonvolatile memory. Furthermore, the processing unit is capable of receiving the measurement signals of the environment sensor and of additional vehicle sensors, and to transfer control signals to at least one safety device.

[0058] The safety device, in a preferred embodiment, is designed as a reversible motor-driven belt tightener (RMBT), which, in an active operational state, can apply adjustable traction to a safety belt. In another preferred embodiment of the invention, additionally or alternatively to the RMBT, additional safety devices are provided, which can be, for example, an electrical window raising device, an electrical adjustment device for a sliding roof, or an electrical seat position adjustment device for automatic setting of a predetermined seat position of a seat in the vehicle.

[0059] In the context of the invention, it is possible, in principle, to use as environment sensor any sensor arrangement by means of which the positions and speeds of objects

located in the surroundings of a vehicle can be determined. In particularly preferred embodiments of the invention, the environment sensor here is in the form of a radar or lidar system, or an infrared sensor system, and it allows at least the determination of objects located in the area in front of the vehicle. Such environment sensors, which are known to the person skilled in the art, are also used in systems for regulating the separation between the vehicle and a preceding vehicle, which already equip many vehicle models. As a rule, they are mounted on the front of the vehicle and they allow the acquisition of objects located in an acquisition area, which is in the form of a segment of a circle that has mirror symmetry with respect to the longitudinal axis of the vehicle. The range of the front sensors currently is approximately 100 m and the opening angle of the segment of the circle is approximately 16°.

[0060] Environment sensors that are equipped with the above sensors as front sensors already make it possible to recognize potential collisions of the vehicle with oncoming objects, particularly oncoming vehicles, as well as potential impacts between the driving vehicle and an object located in front of the vehicle in the front area, both situations representing frequent causes for accidents with severe consequences. In the embodiments described below, reference is made particularly to these situations as examples.

[0061] The object data of acquired objects, which data comprise the position and the speed of the objects and are issued by the environment sensor, relate to a reference system which is fixed with respect to the vehicle, and whose coordinate axes are illustrated in Figure 1, and it will be referred to below as the sensor system. The origin U of the sensor system corresponds to the corner of the acquisition area monitored by the environment sensor, which area is represented in Figure 1 as a surface with a gray background. The x axis points in the vehicle longitudinal direction along the vehicle longitudinal axis, and the y axis points in the direction transverse to the vehicle, along the front vehicle delimitation line towards the left. The superscript index S in the coordinate designation indicates, in the figure and in the following description, that the coordinates or coordinate axes are those of the sensor system.

[0062] The object data which relate to the sensor system which is fixed with respect to the vehicle refer to the relative position $\mathbf{r}^{S}_{Obj} = (x^{S}_{Obj}, y^{S}_{Obj})$ of an object with respect to the origin of the sensor system, which is fixed on the vehicle front, as well as to the relative velocity $\mathbf{v}^{S}_{Obj} = \mathbf{v}^{S}_{Obj} = (v^{S}_{xObj}, v^{S}_{yObj})$ of the object with respect to the velocity of the vehicle. Furthermore, the relative position $\mathbf{r}^{S}_{Obj}$ of the object which is measured by the environment sensor corresponds more accurately to the relative position of the reflection point, at which the signal emitted by the sensor is reflected by the object, where said position is also referred to below again as the relative position of the object.

[0063] The object data are transmitted by the environment sensor to the risk calculator, which also has available, besides the object data, the movement data of the vehicle, such as, particularly, the amount v_F of the vehicle longitudinal velocity, the amount a_F of the vehicle longitudinal acceleration, and the yaw rate $\dot{\psi}$ of the vehicle. These data are determined by corresponding sensors of the vehicle, which are known to the person skilled in the art, such as, rpm sensors and yaw rate sensors, or they are determined from the measurement signals of the vehicle sensors.

[0064] Using the object data, the risk calculator classifies the objects required by the environment sensor, first as comoving, stationary, or oncoming objects. This classification is carried out preferably on the basis of an absolute velocity $\mathbf{v}^{A}_{Obj}$ of the object, where the velocity is with respect to a fixed reference system.

[0065] In a preferred embodiment of the invention, the sensor system is here initialized at a predetermined time as a fixed reference system, so that the latter corresponds to the sensor system at the predetermined time. The absolute position of the vehicle in this system, which is later referred to as the absolute system, is determined from the movement data of the vehicle. In this context, to keep the error, particularly the error resulting from measurement errors of the vehicle sensors, as small as possible in the determination of the absolute vehicle position, the absolute system is preferably newly

initialized at regular time intervals, preferably at each cycle step of the processing unit. The time of the initialization, that is the time of the start of the given cycle step, is defined as the time $t_0 = 0$.

[0066] The classification of the objects acquired by the environment sensor, in the absolute system which has thus been chosen, can be established in a simple manner from the x component v^A_{xObj} of the absolute velocity $\mathbf{v}^A_{Obj}$ of the object. The following applies

$$v^A_{xObj} = v_F - \dot{\varphi} y^S_{Obj} + v^S_{xObj}, \qquad (1)$$

where v_F denotes the vehicle speed, $\dot{\varphi}$ denotes the rate of change of the track angle φ of the vehicle, y^S_{Obj} denotes the y component of the position vector of the object in the sensor system, and v^S_{xObj} denotes the x component of the velocity vector $\mathbf{v}^S_{Obj}$ of the object in the sensor system. The track angle φ is here determined from the sum $\beta + \psi$ of the side slip angle β and the yaw rate ψ of the vehicle, so that the rate of change $\dot{\varphi}$ of the track angle φ, neglecting the rate of change of this side slip angle β, which rate here is the starting point, can be determined from the yaw rate $\dot{\psi}$ of the vehicle.

[0067] The criteria for the object classification are illustrated in the diagram in Figure 2. Accordingly, the object is defined as a comoving or oncoming object, if its velocity component v^A_{xObj} in the x direction of the absolute system is greater than a first tolerance limit v_{x1} or less than a second tolerance limit v_{x2}. Objects, whose velocity component v^A_{xObj} is less than the first tolerance limit v_{x1} and greater than the second tolerance limit v_{x2} are recognized as stationary objects. It has been shown to be advantageous to

choose as the first tolerance limit a value of v_{x1} = 2 m/s and as a second tolerance limit a value of v_{x2} = -2 m/s.

[0068] To avoid a changing classification of objects, whose velocity component v_{xObj}^{A} is in the vicinity of the tolerance limits, a preferred embodiment of the invention carries out the assignment of an object to an object class only when its velocity component v_{xObj}^{A} is located during several sensing cycles within one of the above-mentioned speed ranges defined by the tolerance limits.

[0069] From the object data of the objects that have been classified in the above described manner, the risk calculator then computes the trajectories or the tracks of the objects. In this context, the times that are computed are particularly those at which the trajectories of the objects intersect the vehicle delimitation lines as well as the intersections of the trajectories and the vehicle delimitation lines. Relating only to the collisions between the vehicle and an object where the vehicle impacts head-on with the object, then only the time t_{tc} has to be calculated, at which the trajectory of the object intersects the front vehicle delimitation line, which coincides with the x axis of the sensor system, so that only the relative movement between the vehicle and an object in the vehicle longitudinal direction, that is in the x-direction of the sensor system, needs to be taken into account. This procedure is illustrated in Figure 3.

[0070] The cases of the vehicle approaching an object which are relevant in view of the control of the safety device, and which are evaluated by the risk calculator in the determination of the collision time t_{tc}, are those in which the vehicle moves with constant speed v_F in the forward direction, or in which it is braked until it comes to a stand, and the times at which an object is stationary or moves with constant speed. On the other hand, if the vehicle accelerates in the direction towards the object, it must be assumed that the driver wants to approach, so that this case does not need to be taken into consideration here.

[0071] For objects which were classified as stationary by the risk calculator, the calculation of the collision time t_{tc}, in an advantageous embodiment of the invention, is carried out taking into consideration the rotary movement of the sensor system or of the vehicle when the vehicle moves in a curve, provided the vehicle is not braked. The x component $x^S_{Obj}(t)$ of the relative trajectory $\mathbf{r}^S_{Obj}(t)$ of a stationary object in the sensor system can here be expressed as follows using magnitudes in the absolute system:

$$x^R_{Obj}(t) = x^A_{Obj} \cos(v_F t/\rho) + y^A_{Obj} \sin(v_F t/\rho) - \rho \sin(v_F t/\rho) + l_S \cos(v_F t/\rho) - l_S \qquad (2)$$

ρ here denotes the radius of curvature of the track of the vehicle's center of gravity, which can be determined from the amount v_F of the vehicle speed and (neglecting the rate of change of the side slip angle β) the yaw rate $\dot{\psi}$ of the vehicle. The magnitude l_S is the difference between the origin of the sensor system and the vehicle's center of gravity, that is the separation, measured in the vehicle longitudinal direction, between the vehicle's center of gravity and the vehicle front.

[0072] Because the sensor system and the absolute system at the time of initialization $t_0 = 0$ of the absolute system coincide, it is possible to use, for the calculation of the collision time t_{tc} by the equation 2, the relative coordinates x^R_{Obj} and y^R_{Obj} determined by the environment sensor for the absolute coordinates x^A_{Obj} and y^A_{Obj}. The collision time t_{tc} is obtained from equation 2 using the condition $x^S_{Obj}(t_{tc}) = 0$ and is determined iteratively by the risk calculator using the rapid numerical algorithm.

[0073] The y component of the intersection $\mathbf{r}^S_{Obj}(t_{tc}) = (0,\ y^S_{Obj}(t_{tc}))$ of the relative trajectory $\mathbf{r}^S_{Obj}(t)$ of the object with the front vehicle delimitation line corresponds to the y component of the trajectory at the collision time t_{tc} and it is given by

$$y^S_{Obj}(t_{tc}) = -x^A_{Obj}\ \sin(v_F t_{tc}/\rho) + y^A_{Obj}\ \sin(v_F t_{tc}/\rho) - \rho\ \cos(v_F t_{tc}/\rho) + l_S\ \sin(v_F t_{tc}/\rho) + \rho \quad (3)$$

where, here as well, the relative coordinates x^R_{Obj} and y^R_{Obj} measured by the environment sensor are used for the absolute coordinates x^A_{Obj} and y^A_{Obj}.

[0074] At least in the calculation of the trajectory of objects classified as comoving or oncoming, in an advantageous embodiment of the invention, the starting point is a straight relative movement between the vehicle and the objects, for which the angle between the direction of movement of the vehicle and the directions of movement of the objects are temporally constant. In this approximation, it is thus assumed that both the vehicle and also an object move along a straight line and that the relative movement, in the case of a non vanishing angle between the directions of movement of the vehicle and of the object, in addition, moves along the same pattern. Furthermore, in the case of a movement of an object in the longitudinal direction of the vehicle or against the longitudinal direction of the vehicle as well, an acceleration of the object is neglected, because such any acceleration as a rule cannot be determined, or can be determined only very imprecisely, from the measurement signals of the environment sensor.

[0075] If the vehicle is not braked, the risk calculator here determines the collision time t_{tc} taking this approximation into account, as follows

$$t_{tc} = -\frac{x^S_{Obj}}{v^S_{xObj}}. \quad (4)$$

[0076] The y component of the intersection $\mathbf{r}^S_{Obj}(t_{tc})$ of the relative trajectory $\mathbf{r}^S_{Obj}(t)$ of the object with the front vehicle delimitation line is obtained therefrom as

$$y^S_{Obj}(t_{tc}) = y^S_{Obj} + v^S_{yObj} t_{tc} \tag{5}$$

[0077] If, for a comoving vehicle, the calculation of the collision time t_{tc} using equation 4 yields a negative collision time $t_{tc} < 0$, then a collision with the object in question is ruled out. The corresponding objects are no longer taken into consideration by the risk calculator within the same cycle step.

[0078] If the vehicle is braked with a deceleration of $a_F < 0$, then the collision time is determined both for comoving and oncoming, as well as for stationary, objects by

$$t_{tc} = \frac{-v^S_{xObj} \pm \sqrt{v^S_{xObj} - 2 a_F x^S_{Obj}}}{a_F} \tag{6}$$

The y component of the intersection $\mathbf{r}^S_{Obj}(t_{tc})$ of the relative trajectory $\mathbf{r}^S_{Obj}(t)$ of the object with the front vehicle delimitation line is here determined as

$$y^S_{Obj}(t_{tc}) = y^S_{Obj} + v^S_{yObj} t_{tc} + \tfrac{1}{2} a_F t^2_{tc} \tag{7}$$

If no non-negative collision time t_{tc} can be determined from equation 6, then a collision of the vehicle with the object in question is ruled out, and the object is no longer taken into consideration by the risk calculator within the same cycle step.

[0079] The y coordinate $y^S_{Obj}(t_{tc})$ of the intersection $\mathbf{r}^S_{Obj}(t_{tc})$ determined in the above manner between the relative trajectory $\mathbf{r}^S_{Obj}(t)$ of an object and the front vehicle delimitation line is used by the risk calculator to make a decision to determine whether the vehicle and an object are on a collision course. Because the dimensions of the object cannot be determined by the described environment sensor, which is assumed to be used here, an advantageous embodiment of the invention provides a risk calculator which determines a collision course safety P_{ctrack}, which corresponds to the probability of the existence of a collision course. The dimensions of an object are here estimated in a model.

[0080] In a simple model, it is assumed that the signal of the environment sensor is reflected in the middle of the object, that is that the object, starting from the y coordinate y^S_{Obj} of its position $\mathbf{r}^S_{Obj}$, which is determined by the environment sensor, has the same dimensions towards the left and towards the right. However, test measurements have shown that the reflection point at which the sensor signal is reflected is offset, with respect to the middle of the object, towards the middle of the driving lane of the vehicle. In the case of an object which is located in the middle of the driving lane of the vehicle, the sensor signal is thus reflected at the middle of the object, but, if the object is offset in a direction with respect to the driving lane of the vehicle, the reflection occurs at another point, which is shifted in the opposite direction with respect to the middle of the object. This is illustrated in Figures 4a, 4b and 4c for the cases in which a preceding vehicle is located in the driving lane of the vehicle (Figure 4a) and offset towards the left with respect to the driving lane (Figures 4b and 4c), where the cross in the figures in each case marks the reflection point.

[0081] For the determination of the collision course safety P_{ctrack}, a minimum object width $b_{Obj,min}$ is therefore predetermined, which, for example, for comoving and oncoming objects is 2 m and for stationary objects 1 m.

[0082] Here, an assignment is made between the separation, decreased by the minimum object width, between the determined intersection of the vehicle longitudinal action, which is given by the difference between the amount $|y^S_{Obj}(t_{tc})|$ of the y coordinate $y^S_{Obj}(t_{tc})$ of the intersection and the minimum object width $b_{Obj,min}$, and the collision course safety P_{ctrack}, which is obtained using a potential curve or a potential curve group. Figure 4 is a schematic illustration of a preferred potential curve group, where the separation axis, which would differ for positive and negative values, is not labeled.

[0083] The collision course safety P_{ctrack} assumes the value 1, if the separation $|y^S_{Obj}(t_{tc})| - b_{Obj,min}$ is not greater than the half-width b_F of the vehicle, and is set to 0 if the separation $|y^S_{Obj}(t_{tc})| - b_{Obj,min}$ is greater by at least a predetermined safety separation d_{sa} than the vehicle half-width b_F.

[0084] For increasing separations $|y^S_{Obj}(t_{tc})| - b_{Obj,min}$, which are within the safety area between $b_F/2$ and $b_F/2 + d_{sa}$, the collision curve safety P_{ctrack} decreases. It is preferred here for the collision course safety P_{ctrack} to be within the safety range as a function of the amount v^S_{Obj} of the relative velocity $\mathbf{v}^S_{Obj}$ of an object, where the fact must be taken into account that the collision risk increases, if the vehicle and the object approach each other at a higher velocity. This is due mostly to the fact that at higher velocities, slight steering movements already have an effect on the collision course.

[0085] For example, the collision course safety for the left vehicle side, that is for $|y^S_{Obj}(t_{tc})| - b_{Obj,min} > 0$ can be given by

$$P_{ctrack} = \begin{cases} 1 & , y^S_{Obj}(t_{tc}) - b_{Obj,min} < b_F/2 \\ \left(1 - \dfrac{y^S_{Obj}(t_{tc}) - b_{Obj,min} - b_F/2}{d_{sa} + b_F/2}\right)^{2,3-2k,} & , b_F/2 \le y^S_{Obj}(t_{tc}) - b_{Obj,min} < b_F/2 + d_{sa} \\ 0 & , b_F/2 + d_{sa} < y^S_{Obj}(t_{tc}) - b_{Obj,min} \end{cases}$$

where the group parameter k_v is determined from predetermined parameters v_{min} and v_{max} and the relative velocity v^S_{Obj} of the object:

$$k_v = \begin{cases} \dfrac{v^S_{Obj}}{v_{max}} & , v_{min} < v^S_{Obj} < v_{max} \\ 0 & \text{sonst} \end{cases}$$

[Note: G. sonst = E. otherwise]

[0086] Furthermore, the risk calculator determines for each object acquired by the environment sensor, for which a collision course safety P_{ctrack} different from zero was determined, the maximum length of time Δt_{pcu} which remains available to the driver of the vehicle to start a driving maneuver to prevent a collision with the object. This corresponds to the length of time up to a time after which a collision can no longer be prevented by starting a driving maneuver. Driving maneuvers here include both brake maneuvers and also avoidance maneuvers for collision prevention.

[0087] For the length of time $\Delta t_{pcu,br}$, after which at the latest a braking of the vehicle must be started to prevent a collision with an object, the following holds

$$\Delta t_{pcu,br} = -\frac{x^S_{Obj,0}}{v_{rel,0}} - \frac{v_{rel,0}}{2a_{F,max}}, \tag{8}$$

where, here as well, for the calculation of a straight relative movement between the vehicle and the object, it is assumed that there is a straight relative movement between the vehicle and the object, during which the object is not accelerated. The acceleration $a_{F,max}$ here denotes the maximum deceleration of the vehicle which can be achieved with

full braking. If the full braking occurs on a dry, asphalt-covered road (corresponding to a friction of $\mu = 1$) and if the tires of the vehicle are at the adhesion limit, the theoretically possible value obtained is $a_{F,max} = 10$ m/s, and it is used preferably in the calculation of the length of time $\Delta t_{pcu,br}$. Although this value in general is not reached during the full braking because of a non-ideal brake force distribution and above all because of an actual lower adhesion factor μ, this value nevertheless allows a reliable statement regarding the length of time $\Delta t_{pcu,br}$ after which a collision can no longer be prevented by braking the vehicle.

[0088] In the determination of the length of time $\Delta t_{pcu,st}$ up to the latest time at which an avoidance maneuver can be started by the driver to prevent a collision with an object, it is assumed that the avoidance maneuver has no effect on the collision time t_{tc}. This assumption, as a rule, is justified, because the velocities in the longitudinal direction of the vehicle, as a rule, are clearly higher than those in the direction transverse to the vehicle. The length of time $\Delta t_{pcu,st}$ can thus be calculated as the difference between the collision time t_{tc} and a length of time Δt_{st} which is required to produce the transverse offset of the vehicle required for the avoidance maneuver.

[0089] Like the length of time $\Delta t_{pcu,br}$, the length of time $\Delta t_{pcu,st}$ is determined as the maximum length of time remaining until the driving maneuver has to be started, so that the minimum length of time Δt_{st} required for an avoidance maneuver is appropriate, and calculated under the assumption of a maximum possible transverse acceleration of the vehicle. However, the maximum transverse acceleration, which occurs during an avoidance maneuver, is only built up gradually during the change in the steering angle, which results from the steering movement which the driver performs to execute the avoidance maneuver. Furthermore, the change in the steering angle leads to a rotating movement of the vehicle about the vertical axis, which, on the one hand increases the transverse acceleration while, on the other hand, reducing the vehicle speed. Thus, the starting assumption here is not a maximum achievable transverse acceleration in the calculation of the length of time Δt_{st}, but rather an average maximum transverse

acceleration $\bar{a}_{y,max}$. Here a value of $\bar{a}_{y,max} = 8\ m/s^2$ has been shown to be particularly advantageous.

[0090] The transverse offset Δy_{st} of the vehicle, which is required for an avoidance maneuver to the left and to the right is calculated separately, where, for the determination of the width of the object, it is again preferred to use the already described object model. In particular, in this context, it is assumed that the object presents different lateral dimensions to the left and to the right of the reflection point. With regard to the object's dimension $b_{Obj,l}$ to the left, a maximum dimension $b_{Obj,max}$ is assumed, if the y coordinate $y^S_{Obj}(t_{tc})$ of the intersection of the object trajectory with a front vehicle delimitation line is positive and greater than the half vehicle width $b_F/2$, and the minimum dimension $b_{Obj,min}$ is assumed, if the y coordinate $y^S_{Obj}(t_{tc})$ of the intersection of the object trajectory with the front vehicle delimitation line is negative and greater than the half vehicle width $b_F/2$. If $-b_F/2 < y^S_{Obj}(t_{tc}) < b_F/2$, it is assumed that the object's dimension $b_{Obj,l}$ decreases linearly with increasing value of $y^S_{Obj}(t_{tc})$. The course of the object's dimension $b_{Obj,1}$ to the right is illustrated in the diagram in Figure 6.

[0091] The object's dimension, starting from the reflection point, towards the right is determined analogously. It can be illustrated by a curve, corresponding to the curve shown in Figure 6, except that the curve is mirrored with respect to the vertical axis.

[0092] The required transverse offset $\Delta y_{st,1}$ for an avoidance maneuver to the left is thus given by

$$\Delta y_{st,l} = y^S_{Obj}(t_{tc}) + b_F/2 + b_{Obj,l} + D_{sa} \qquad (9)$$

where the magnitude D_{sa} is an optionally considered safety separation, which should exist after the avoidance maneuver between the vehicle and the object. It is preferred for

the safety separation D_{sa} not to be chosen to be greater than the safety separation d_{sa}, because otherwise, for objects with non vanishing collision course safety P_{ctrack}, negative values could be calculated for the transverse offset $\Delta y_{st,l}$. The required transverse offset $\Delta y_{st,r}$ for an avoidance maneuver to the right is obtained analogously.

[0093] Furthermore, the risk calculator checks whether room for an avoidance maneuver is actually available, or whether the vehicle, as a result of an avoidance maneuver to avoid a collision with a first object, will be brought into a collision course with a second object. This verification is carried out under the assumption that the driver of the vehicle considers performing an avoidance maneuver only if it leads to a clear improvement of a dangerous situation. Therefore, an avoidance possibility is ruled out by the risk calculator, if a length of time $\Delta t_{tc,min}$ up to a potential collision with an additional object is not reached in the required avoidance zone. For example, this length of time is set to $\Delta t_{tc,min} = 5$ sec.

[0094] To test the possibility of avoidance to the left, the risk calculator first verifies in a first step whether at least one intersection of a trajectory of an object acquired by the environment sensor is within a predetermined collision avoidance range d_{caa}, which is determined by a predetermined interval on the positive y axis of the sensor system. Such an intersection is thus recognized if, for at least one object, $0 \leq y^{R}_{Obj}(t_{tc}) \leq d_{caa}$. If a subsequent verification of the collision time t_{tc}, which was calculated for the objects determined in the first step, indicates that the length of time up to the collision time t_{tc} is less than the length of time $\Delta t_{tc,min}$, then the possibility of an avoidance maneuver to the left is ruled out. Similarly, for evaluating the possibility of an avoidance maneuver to the right, a verification is conducted first in a first step to determine that $-d_{caa} \leq y^{R}_{Obj}(t_{tc}) < 0$ for at least one object. The possibility of an avoidance maneuver to the right is ruled out, if the length of time up to the collision time t_{tc} of an object determined in the first step is less than the length of time $\Delta t_{tc,min}$.

[0095] If the possibility of an avoidance maneuver to the left is not ruled out, then, subsequently, for this object, a length of time $\Delta t_{pcu,st,l}$ up to the latest time at which an

avoidance maneuver to the left must be started by the driver to prevent a collision with an object is determined, which, according to the statements made above, is given by

$$\Delta t_{pcu,st,l} = t_{tc} - \sqrt{2 y_{st,l} / a_{y,max}} \qquad (10)$$

If the possibility of an avoidance maneuver to the right is not ruled out, then, for the object, a length of time $\Delta t_{pcu,st,r}$ up to the latest time at which an avoidance maneuver to the right must be started by the driver to prevent a collision with the object is determined, and it is given by

$$\Delta t_{pcu,st,l} = t_{tc} - \sqrt{2 y_{st,r} / a_{y,max}} \qquad (11)$$

The length of time $\Delta t_{pcu,st}$ up to the latest time at which an avoidance maneuver must be started by the driver to prevent a collision with an object, is determined therefrom as the maximum of the two lengths of time $\Delta t_{pcu,st,l}$ and $\Delta t_{pcu,st,r}$ determined by the risk calculator:

$$\Delta t_{pcu,st} = \max\left(\Delta t_{pcu,st,l}, \Delta t_{pcu,st,r}\right) \qquad (12)$$

[0096] The length of time Δt_{pcu} up to the latest time at which a driving maneuver must be started by the driver of the vehicle, is obtained as the maximum of the length of time $\Delta t_{pcu,br}$ and the length of time $\Delta t_{pcu,st}$, so that the following holds:

$$\Delta t_{pcu} = \max\left(\Delta t_{pcu,st}, \Delta t_{pcu,br}\right) \qquad (13)$$

[0097] In a preferred embodiment of the invention, the length of time Δt_{pcu} so determined is used to determine an accident nonavoidance probability dp_{acc}, which indicates the probability that the driver will not start a driving maneuver for collision prevention. It is calculated preferably from the ratio between the length of time Δt_{pcu} and an additional length of time Δt_{crit} in the form

$$dp_{acc} = 1 - \frac{\Delta t_{pcu}}{\Delta t_{crit}} \qquad (14)$$

The length of time Δt_{crit} here preferably corresponds to the legally prescribed minimum separation between two vehicles, which in Germany is half of the value of the vehicle's longitudinal speed v_F in meters ("half tachometer rule") and thus a temporal separation of 1.8 sec. Using the accident nonavoidance probability dp_{acc} and the collision course safety P_{ctrack}, the risk calculator subsequently determines for each object acquired by the environment sensor, which does not have a vanishing collision course safety P_{ctrack}, the danger potential dp, which is calculated preferably as the product of these two magnitudes, so that the following holds:

$$dp = dp_{acc} \cdot P_{ctrack} \qquad (15)$$

Furthermore, for each object for which the collision course safety P_{ctrack} is greater than zero, an accident severity σ is determined in advantageous embodiments of the invention. The latter value has a magnitude between 0 and 1, where the value $\sigma = 0$ then should be assigned if a potential impact with the object does not entail any risk to the passengers, while the value $\sigma = 1$ should be assigned to a potential accident with fatal consequences for the vehicle passengers. The determination of the accident severity σ is preferably made as a function of the impact speed v_c, which corresponds to the amount of the relative velocity $\mathbf{v}^S_{Obj}(t)$ between the vehicle and the object at the collision time t_{tc}. If

the relative velocity is assumed to be constant here, then the amount v^S_{Obj} of the relative velocity $\mathbf{v}^S_{Obj}$, measured by the environment sensor, can be used as the basis.

[0098] The assignment between an impact speed v_c or the amount v^S_{Obj} of the relative object velocity $\mathbf{v}^S_{Obj}$ and the accident severity σ can be made using a characteristic line, as illustrated, for example, in the diagram in Figure 7. For values of the relative impact speed v_c which are greater than a predetermined threshold value, the accident severity σ then assumes the value 1. For lower values of the impact speed v_c, the accident severity σ increases preferably as the square, because the kinetic energy, which is transferred in an accident, also increases as the square with the relative impact speed v_c.

[0100] An additional characterization of a possible collision between the vehicle and an object is also made possible by calculating the collision angle θ, which is the angle between the front vehicle delimitation line, or the y axis of the sensor system, and the direction of movement of the object at the collision time t_{tc}. For objects which were classified as stationary, it is assumed that if there is a collision it will be a frontal impact, so that for these objects a collision angle of $\theta = \pi/2$ is always set. For objects which were classified as comoving or oncoming, the risk calculator, with the approximation in the form

$$\theta = \arctan \frac{v^A_{xObj}}{v^A_{yObj}} \qquad (16)$$

which was already presented in the context of the calculation of the trajectories of the objects, is used, where here the x component v^A_{xObj} of the absolute velocity of the object,

indicated in equation 1, is used for the calculation. The analogous expression for the y component v^A_{yObj} is

$$v^A_{yObj} = l_S\dot{\varphi} + \dot{\varphi}x^R_{xObj} + v^R_{yObj} \qquad (17)$$

[0101] The above described magnitudes are determined for each object acquired by the environment sensor or for each acquired object with a collision course safety P_{ctrack} different from zero. After the calculation of the magnitudes, the risk calculator determines the object which represents the greatest danger for the vehicle or its passengers. In preferred embodiments of the invention, the risk calculator here determines the object for which the highest danger potential dp or the smallest collision time t_{tc} was calculated. The control of the safety devices, and particularly of the RMBT is then carried out as a function of the magnitudes that were calculated for the object, which was identified by the risk calculator as the object associated with the highest danger.

[0102] In a preferred embodiment of the invention, a determination is made of, not only the deactivated operational state of the RMBT, which exerts no force on the safety belt, but also of three additional operational states, in which the traction used by the RMBT for tightening the safety belt is 50 N, 150 N and 250 N, so that the control occurs in three steps. The force steps are referred to below as a first, second and third step.

[0103] The control of the RMBT is illustrated in the diagram in Figure 8. For the activation of the RMBT, the risk calculator here first determines, from the measurement signals of a corresponding sensor, which one of the safety belts equipped with RMBT in the vehicle must be engaged with the associated belt lock. The i^{th} step of the RMBT of the engaged safety belt is activated by the risk calculator, if the collision time t_{tc} calculated for the most dangerous object falls below a threshold value S^i_t, and if the danger potential dp calculated for this object exceeds a threshold value S^i_{dp}. The threshold values are

preferably indicated as a function of the accident severity σ calculated for the most dangerous object and of the collision angle θ calculated for the most dangerous object.

[0104] The following here holds

$$S_t^i = t_{base}^i + \eta_\sigma^i \sigma - \eta_\theta^i (1 - \sin\theta)$$

and

$$S_{dp}^i = 1 - (1 - dp_{min}^i)\sigma \sin\theta$$

[0105] The magnitude t_{base}^i here gives the base threshold value for the activation of the force step i of the belt tightener, and it is, for example, t_{base}^1 = 720 ms for the activation of the first step, t_{base}^2 = 520 ms for the activation of the second step, and t_{base}^3 [sic] for the activation of the third step. The additional contributions to the threshold value S_t^i take into account the calculated accident severity σ and the collision angle θ, which are weighted by the parameters

η_σ^i and η_θ^i. The threshold values S_{dp}^i are determined particularly from the predetermined base danger potential dp_{min}^i.

[0106] After a first force step has been activated, a higher step is activated, as soon as the conditions for its activation are met. However, if the collision time t_{tc} exceeds the threshold value S_t^i and/or the danger potential dp falls below the threshold value S_{dp}^i, while the i^{th} step of the belt tightener is activated, then this step still remains activated for a length of time Δt_{active} of, for example, 3 s. As a result, an activated belt tightener is prevented from being deactivated during a maneuver for collision avoidance, which would cause considerable irritation for the driver of the vehicle, and would affect the execution of the maneuver. If the collision time t_{tc} is lower than the threshold value S_t^i, and if the

danger potential is greater than the threshold value, the risk calculator therefore first verifies, as illustrated in Figure 8, whether the RMBT is active. If this is not the case, it activates step i of the RMBT. If the RMBT is active, then a verification is performed in a second verification step, to determine whether the step i is higher than the instantaneously activated step, and it activates the step i, if this is the case. However, if the step i is less than the instantaneously activated step, then, in an additional verification step, a verification is carried out to determine whether the length of time Δt_{active}, which starts with the activation of a step, has elapsed. If this were the case, an RMBT would be deactivated. If the length of time Δt_{active} has not elapsed, then the instantaneous step is maintained.

[0107] As already mentioned, additional safety devices are used, namely electrical window raising devices, by means of which windows of the vehicle can be closed in time before a potential accident, an electrical setting device to close a sliding roof of the vehicle and/or automatic seat adjustments, which bring the seats in the vehicle in an advantageous upright position. These are safety devices which can be operated in an inactive or active state.

[0108] The control of these safety devices therefore occurs in a single step as a function of a comparison of the collision time t_{tc} and/or the danger potential dp of the object, which was ranked as the object entailing the greatest danger. In particular, in this context, threshold values for the collision time t_{tc} and/or the danger potential dp are predetermined for each additional safety device, where the activation of a safety device occurs if the collision time t_{tc} is less than the corresponding threshold value and/or the danger potential dp is greater than the corresponding threshold value.